SECTION 23 – ACOUSTICS

23.1 GENERAL ISSUES

23.1.1 Introduction. This Section deals with guidelines, criteria, and general approaches to sound problems in military health care facilities. This information is designed to help a design professional or facility program manager understand some of the causes of sound/noise problems, and the tools that are available to address them. The section covers General Issues (definitions and metrics, sources and receivers), Sound Isolation (separation of sound and speech privacy between spaces), Room Acoustics (control of noise within spaces), Mechanical System Noise and Vibration Control, and Implementation Guidelines (integration and execution of acoustics through planning, design, construction, and post-construction phases of a project). Additional requirements and design guidance relating to acoustical design is contained at Section 8 (HVAC) and Appendix A of this document.

23.1.2 Analysis

23.1.2.1. Problems covered. This section is directed to acoustics problems in health care facilities such as speech privacy between offices, sound isolation between patient rooms, proper level and character of ambient (background) sound in rooms, control of noise and vibration from mechanical equipment in buildings, good hearing conditions in public spaces, and general noise control in work environments.

23.1.2.2. Problems not covered. This section does not address advanced acoustics problems such as performance spaces (e.g., lecture rooms, cinemas or theater), specialized laboratory or meeting spaces (e.g., wind tunnels, animal research facilities, video teleconference rooms), or highly vibration-sensitive equipment (e.g., electron microscopes, laser surgery).

23.2 SOUND ISOLATION.

23.2.1 Introduction. Sound isolation is important in military health care facilities in order to provide privacy for sensitive conversations, comfort for patients, and isolation of annoying and loud sound levels from equipment. The STC rating of various constructions (grouped components making up partitions, doors, windows, floors, etc) which define a space, and Flanking Sound Transmission are two important variables having the most impact on sound isolation, and which must be consciously controlled by the medical facility designer.

23.2.1.1 Sound Transmission Class (STC). STC is the standard single-number measure of the ability of a material or construction system to block sound. STC values are used in this section to determine suitable design. STC is derived from Transmission Loss data measured in a controlled laboratory environment. A higher STC number indicates better sound isolation. STC values can range from STC 0 (block no sound) to STC 70 or higher (almost no sound gets through), but in practical terms, general constructions in most buildings range from STC 30 to STC 55 or so. Because STC ratings are determined from laboratory tests, they eliminate variations that would be related to field installation factors such as size of room, room absorption, edge conditions, sound leaks, quality of workmanship, and such. Minimum STC ratings for the envelope components of each room are listed in Appendix “A”. These minimum ratings are intended to assist the medical designer, who will utilize them along with professional judgement, in providing the amount of privacy required.

23.2.1.2 Flanking Transmission. Flanking sound paths are sound paths that go from one space to another by secondary paths, not through the primary wall or floor. Flanking paths can be through a corridor, laterally through a roof or floor plane, and through gaps and cracks in construction. Figure 23.2 and 23.3 indicates transmission paths and some example construction options the medical facility designer should consider when providing for various levels of sound isolation for adjacent spaces.

23.2.1.3 Other terms. Other terms pertinent to sound isolation review are defined in appendix "E".

23.2.2 Constructions. This section describes different construction types and explains how they can be evaluated for their ability to block sound.

23.2.2.1 Partitions. The medical facility designer should provide partitions which meet the requirements found in appendix A. A large amount of material is available from suppliers which provide examples of standard wall assemblies and list the associated STC ratings. Typical single layer gypsum partitions for steel framing (with wall boards staggered) normally can achieve an STC rating of 40, however with the inclusion of glass fiber in the wall cavity the STC ratings increase to around 47. Double layer gypsum partitions have STC ratings ranging from 46 (without cavity bats) to around 53 (with cavity bats), both having base layers vertical and face layers horizontal, with joints staggered). All STC ratings are verified with an associated test number.

a. Acoustical Insulation: Lightweight porous fibrous insulation can be a glass fiber or a mineral fiber batt. At least one side of the insulation should be unfaced. The density of the insulation should be around 24 to 64 kg per cubic meter (1 to 3 pounds per cubic foot). Careful consideration should be given to limiting the use of fibrous insulation in partitions where flexibility is a concern; the insulation could hamper the ability of adding or relocating plumbing, voice/data outlets or electrical outlets in the future.

b. Flanking transmission: The most common flanking paths at partitions are the joints between the partition and the adjacent floor, wall, and ceiling elements. To achieve the full sound isolating capabilities of a partition, be sure details are provided for continuous beads of sealant at the floor and ceiling joints of the partition (Figures 23.1 and 23.3).

c. Recessed services: Where service elements (e.g., electrical outlets, telephone or data plugs) are recessed into sound isolating partitions, as will often occur, they should be backed or encased with gypsum board, plaster, or other impervious material equal to the surface weight of the partition. Designers should provide appropriate details in design plans.

d. Surface mounted equipment: Vibrating equipment (such as medical instruments with electrical motors), should not be mounted on wall surfaces adjacent to acoustically sensitive spaces.

23.2.2.2 Ceiling Systems. The medical facility designer shall take into account that ceiling systems are critical factors in sound isolation when wall constructions do not extend to the floor above. Sound isolation through an average suspended mineral fiber acoustic tile is seldom greater than STC (or CAC) 35 to 39. Glass fiber acoustic tile ceilings are far worse, with STC or CAC ratings less than 25. Sound travels through the ceiling, into a common plenum, and then into neighboring spaces through the ceiling again. These ratings are often further degraded by return air slots, registers, and grilles, and recessed light fixtures with openings to a return air plenum. The medical facility designer shall evaluate the following elements with respect to providing required sound isolation:

a. Ceiling/wall joint: A continuous, suspended ceiling system should not extend over adjacent acoustically sensitive spaces that require confidential speech privacy, such as examination rooms. The ceiling system should be cut or interrupted at the line of the intervening partition.

b, Plenum barrier: To minimize sound transmission between acoustically sensitive spaces, a sound isolation barrier should be provided in the plenum space between the suspended ceiling and the underside of the structure above, following the line of the partition below and extending along perpendicular walls as well. The plenum barrier must consist of a dense, impervious material such as gypsum board, but need comprise only one layer of gypsum board. Superior to this construction is a full-height slab-to-slab partition system wherever possible. See construction type #1 in Figure 23.3.

c. Insulation on top of the partition: When a construction, slab to slab barrier is not provided, the medical facility designer shall consider insulation on top of the partition. In order to improve the sound isolation through the acoustic tile ceiling (that is, to achieve a higher CAC rating), 75mm (3-inch) thick, foil-backed noncombustible blanket of insulation material such a glass fiber or mineral wool may be installed, foil side down, on top of the suspended ceiling system. This blanket should extend 1200mm (4 feet) from each side of the partition below. This acoustical insulation works best when the plenum depth is less than 400mm (16 inches) high. Care must be taken so that moisture is not trapped in the ceiling space and heat dissipation of light fixtures in not impaired. See construction type #2 in Figure 23.3. Disadvantages to this system are that when maintenance operations occur at the ceiling in the future, the insulation is often removed or damaged and not put back in place or repaired properly.

d. Special acoustical tile ceilings: Where plenum barriers and insulation are impractical, the medical facility designer shall consider utilizing special acoustical tile with a higher CAC than standard (35-39). See construction type #3 in Figure 23.43.

e. Solid ceilings: When required to provide the required degree of sound isolation between spaces, and when permitted by Appendix A, a suspended sound barrier ceiling, consisting of a dense, impervious, noncombustible material such as gypsum board or plaster, should be considered.

23.2.2.3 Floors. The type of floor construction used between spaces shall be selected and detailed to achieve the required degree of airborne and impact sound isolation. Airborne and impact isolation provided by a floor system are different characteristics of construction, and each shall be considered separately.

a. Flanking transmission. Typical flanking paths of airborne noise, which shall be evaluated in medical facility design include mechanical and elevator shafts, piping, conveyor, and pneumatic tube penetrations.

23.2.2.4 Doors. Doors (and windows) are usually limiting elements in the sound isolation of a construction system. Typically, since corridors are not used as waiting (or otherwise normally occupied) spaces, the overall STC rating of the corridor door/framing system is not critical. However solid door (leaf) meeting the STC class requirement in Appendix A, shall be provided. Special applications may require very limited undercuts, or possibly gasketing. When a door occurs in a partition separating noise critical spaces, special attention should be given to minimizing the undercut and or gasketing. In other words, in rooms for which full isolation is required, the door should provide the same corresponding degree of sound isolation as the walls, floor and ceiling.

23.2.2.5 Windows. Windows, as doors, are also limiting elements in the sound isolation of a construction system. In the same manner, windows normally are not a major factor unless they are part of a wall construction, which is between two spaces requiring sound isolation. In this case, the medical facility designer shall evaluate the effectiveness of the composite construction (window and wall); see section 23.2.3. In special cases, attention must be given to providing sound limiting window constructions to eliminate outside noise sources. In this case the medical facility designer shall evaluate alternative solutions. In addition, designers shall coordinate with the security considerations in other sections of this document.

23.2.2.6 Operable partitions. The sound isolation provided by operable partitions depends to a great extent upon the effectiveness of the perimeter seals. A good seal is difficult to maintain at the perimeter of these partitions, and the actual sound isolation provided often falls far below laboratory test ratings. From an acoustical standpoint, operable partitions should be avoided where possible.

23.2.3 Composite Construction.

23.2.3.1 General. Composite constructions commonly occur in health care facilities where the intervening construction systems contain doors, windows, and suspended ceilings that have different STC ratings. To achieve the required degree of sound isolation and speech privacy between the spaces, the weighted contribution of each construction element in the system should not be significantly lower than any other. The elements shall be weighted by their STC value and the percent of the total wall area involved. To achieve balanced contribution of sound energy through each element of a composite construction, use the following approximation, based on the relative size of each element.

Area of element relative to total area of wall	Allowable NR (or STC) of element relative to NR (or STC) of wall (dB)
less than 25%	-5 to –7
25% to 50%	-2 to –3
greater or equal to 50%	0

For example, to maintain balanced construction, a door in a partition can have a Noise Reduction (or STC) of 5 dB to 7 dB less than the wall, if the size of the door is smaller than 25% of the size of the wall. If the NR (or STC) of the wall is 40, the NR (or STC) of the interconnecting door should be 33 to 35.

23.2.3.2 Detailed calculation. If the above general guidelines and relationships are inadequate for a pertinent analysis, then use Figure 23.4. for more accuracy. As an example, consider the situation of a partition with a door in it, as in the following computations:

a. Area of Partition: 12.5 feet x 8 feet = 100 square feet
Area of Door: 3 feet x 7 feet = 21 square feet
Therefore, the door is 21% of the total wall area

b. If the STC of the partition is 38 dB, and the STC of the door is 30 dB, the difference between the two STC values is 8 dB.

c, From Figure 23.4, the reduction of the NR of the partition is 5 dB.

d. Therefore the total STC of the composite construction is 38 – 5 = STC 33.

23.2.4 Proposed Ratings and Criteria.

23.2.4.1 Accepted Standards for STC ratings. Constructions should be selected to meet the STC ratings listed in Appendix “A”. STC values should be determined for composite constructions. See Section 23.2.3 above. Where partitions do not extend to the structure above, sound transmission through ceilings must be considered in the determination of the composite STC performance. See Section 23.2.2.2 above.

23.2.4.2 Other Design Considerations. Following are pertinent detail issues to address in the design. Detailed discussion of all these items is covered in other parts of this section.

a. Ceilings: Sound transmission through the ceiling plenum by way of the suspended ceiling systems must be addressed through upgrading the ceiling path or with a plenum barrier. See Section 23.2.2 above.

b. Partitions: Include acoustical caulking at the tops and bottoms of partitions. See Section 23.2.2.1.b above.

c. Doors: Interconnecting doors between sensitive spaces should have perimeter gaskets in order to create an air-tight seal. Avoid undercutting or door louvers at these door locations. Sensitive spaces are rooms that require a high degree of privacy, such as interconnecting exam or treatment rooms, or provider offices. See Section 23.2.2.4 above.

d. Equipment noise: Watch for sounds produced by noisy items of equipment in special purpose rooms, where the noise is transmitted through walls and ceilings into adjoining spaces. A notable example is a toilet room with wall-hung fixtures adjacent to a conference room. See Section 23.2.2.1.d above.

e. Cross-talk: Sound can be transmitted through short ventilation ducts with registers in different rooms. See figure 23.7 for suggested duct layout to avoid this problem and as discussed later in this section.

f. Flanking: Sound transfer can easily occur through poorly designed or installed recessed light fixtures in the ceiling, through electrical outlet boxes, or other penetrations located opposite each other on a party wall. See Section 23.2.2.1.b and c, and 23.2.2.2.e.

23.2.5 Structure-borne sound isolation. Structure-borne sound refers to sound whose energy is transmitted directly into and through the structure of a building. The most common single-number rating system to evaluate and compare isolation of impact sound of a floor/ceiling system is the Impact Insulation

Class (IIC) rating system. In terms of criteria, the values are roughly analogous to the STC ratings (that is, if an adjacency requires an STC 40 wall or floor construction, then a similar adjacency probably requires an IIC 40 rating for impact noise).

23.2.5.1 Carpet. With structural concrete floor systems, most structure-borne impact noise can be alleviated with the use of carpet, even a thin industrial carpet. If hard flooring is necessary, try to keep heavily trafficked areas directly above other less sensitive areas that are also heavily trafficked.

23.2.5.2 Carts. Noise sources, such as rolling carts, should have soft rubber wheels to minimize impact noise generation.

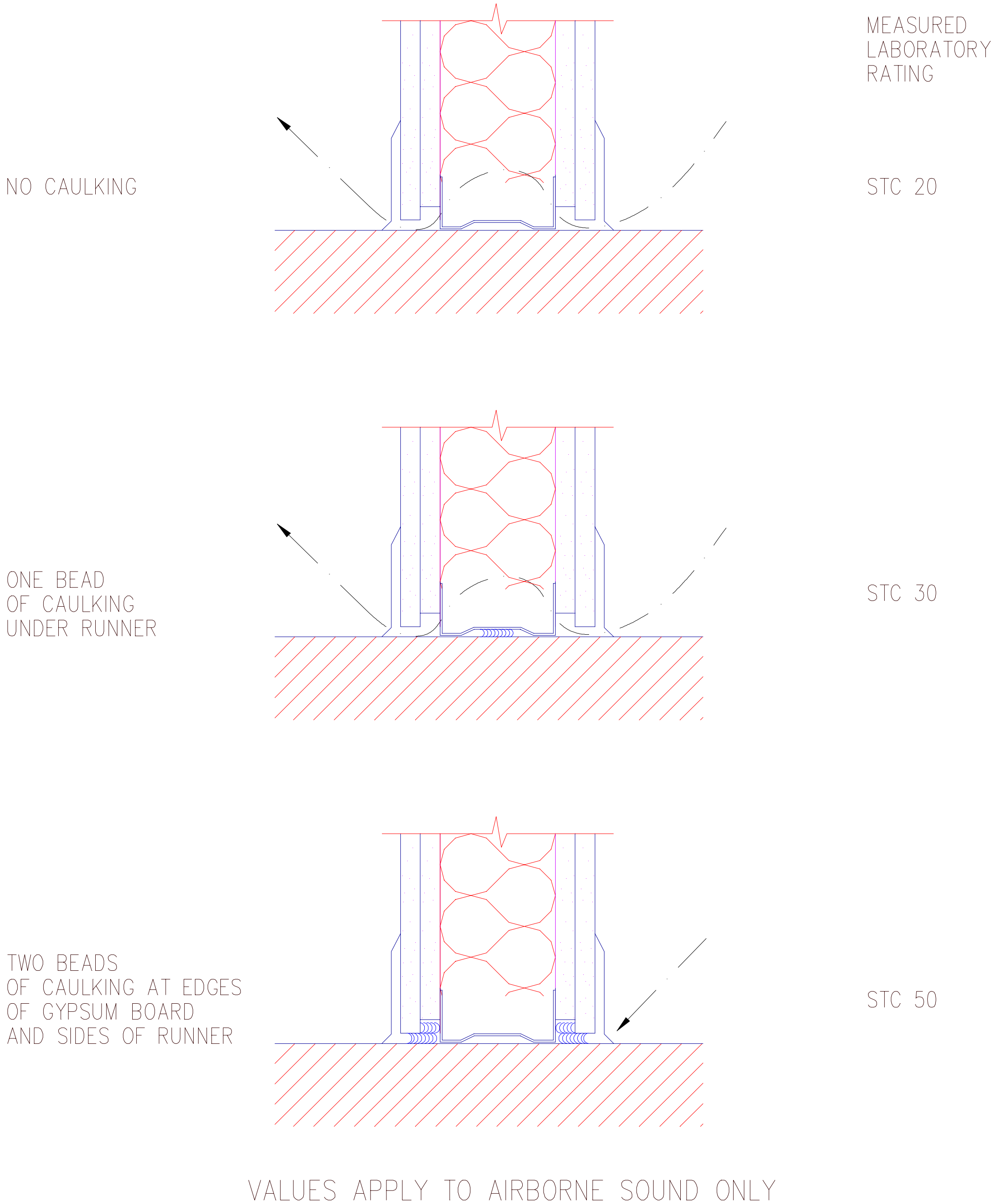
23.2.6 Speech Privacy. The speech privacy obtained between spaces depends upon both the sound isolation provided by the intervening construction systems STC and the ambient noise level NC of that particular receiver space. Recommended ambient noise levels and STC ratings are listed, room by room, in Appendix "A". It is important to provide the proper degree of speech privacy between acoustically sensitive spaces, such as doctors' offices and examination/treatment rooms. The approximate degree of speech privacy between spaces can be estimated using the following relationships:

Speech Privacy Rating = STC+ NC

Speech Privacy Rating	Approximate degree of Speech Privacy
55	none
60 to 70	normal
65 to 75	Moderate
70 to 80	Confidential
>80	Complete

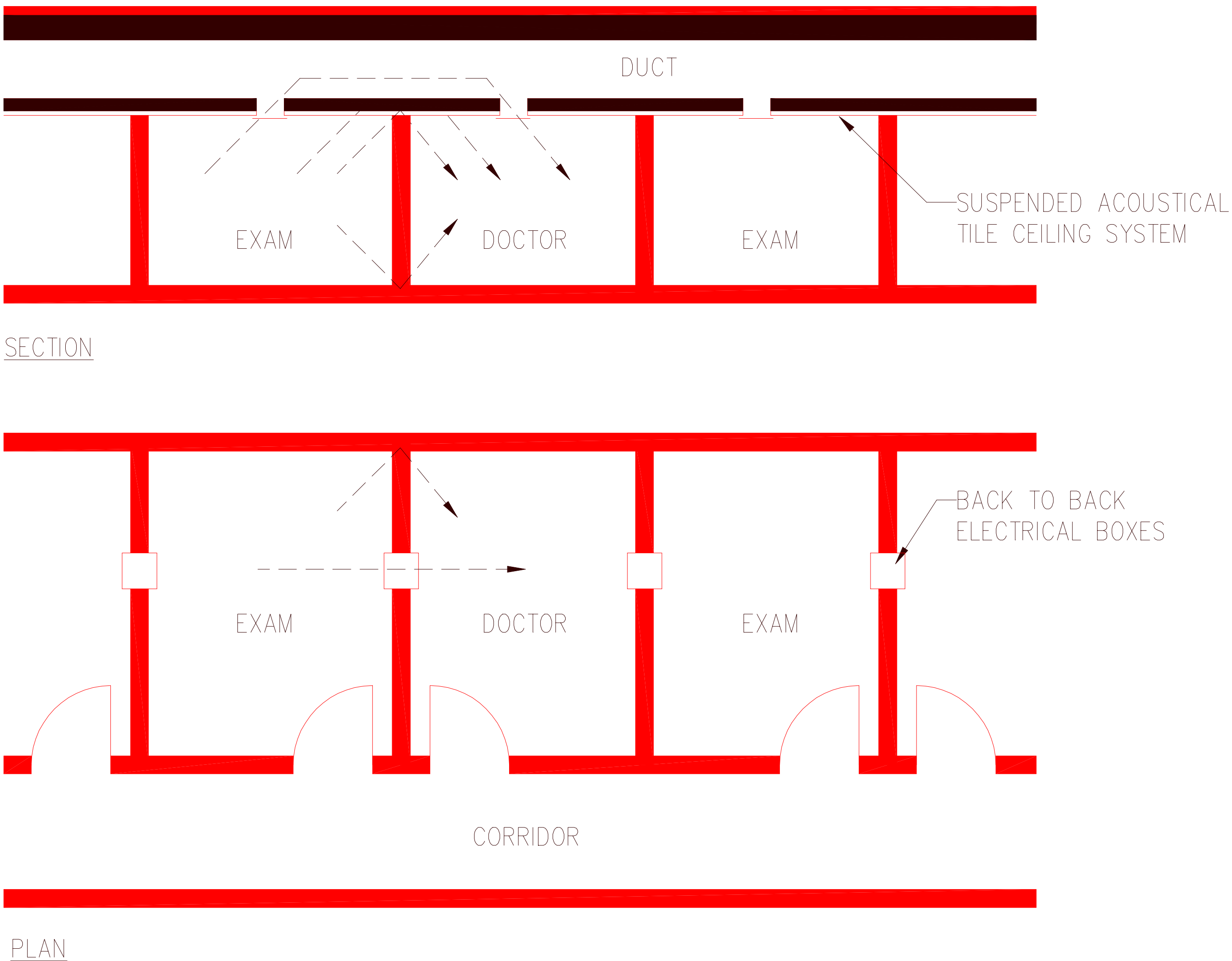
The recommended ambient level in an examination room is NC-30 to NC-35, and the recommended isolation between an examination room and private office is STC 45. The sum is 75 to 80 which will provide a moderate-to-confidential degree of speech privacy between the two spaces. If, however, the wall/ceiling construction provided only STC 25 due to an accordion type folding door, or if the background sound level were only NC-20 to NC-25 while the ceiling CAC were only CAC 35, then the STC + NC total would be 55 to 60, which provides a none-to-normal degree of speech privacy. This degree of speech privacy is not acceptable for an examination room.

23.2.6.1 Sound Masking. Speech Privacy Ratings can be boosted when STC ratings are low or background NC levels are too quiet by the addition of background sound masking. This approach introduces low level broadband inconspicuous background sound, like air conditioning noise, at levels around NC-40. This masking sound covers over the intrusion of a neighbor's intelligible speech. The electronic sound is distributed through loudspeakers hidden above the ceiling.



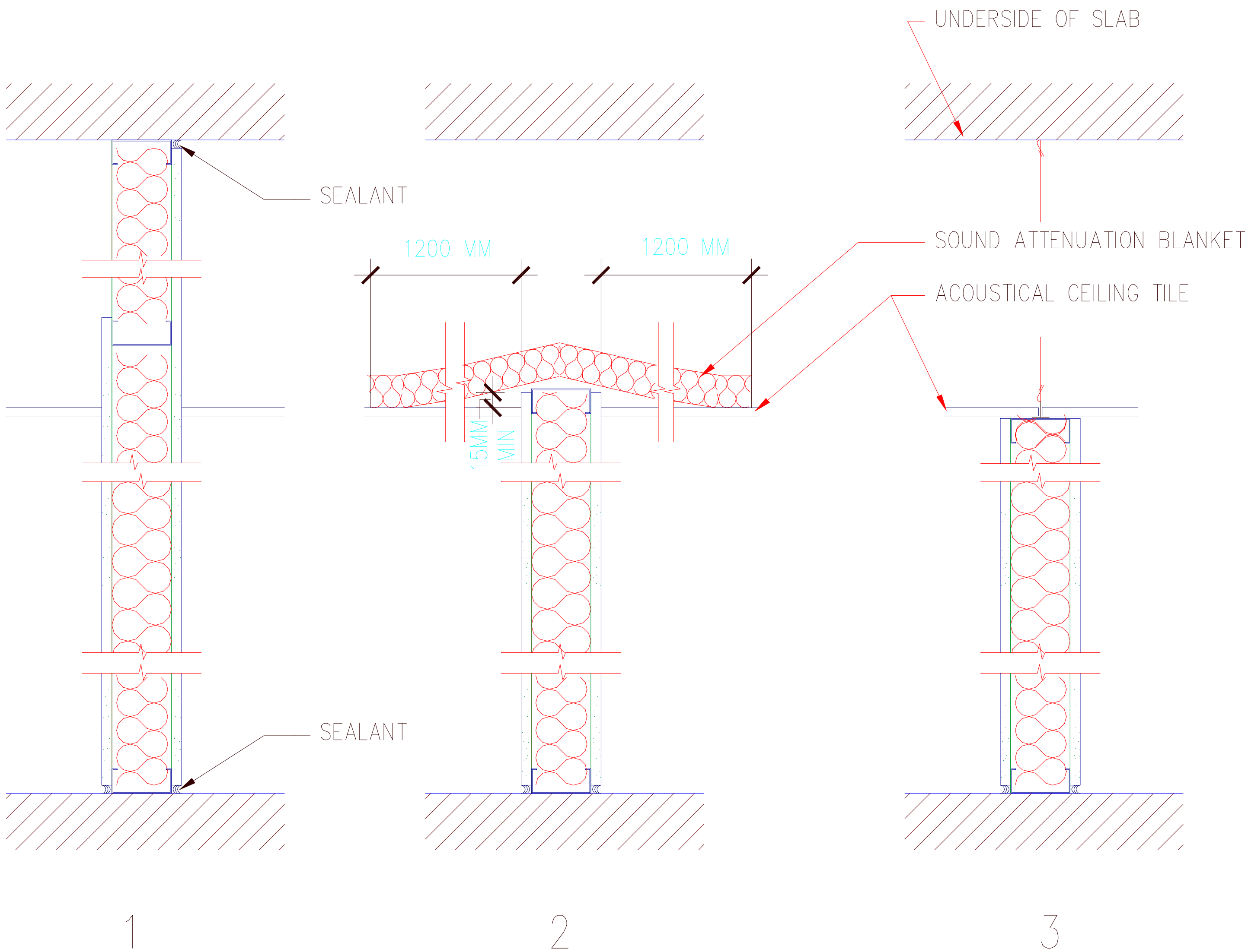
SOUND ISOLATION OF PARTITIONS BY CAULKING

Figure 23.1



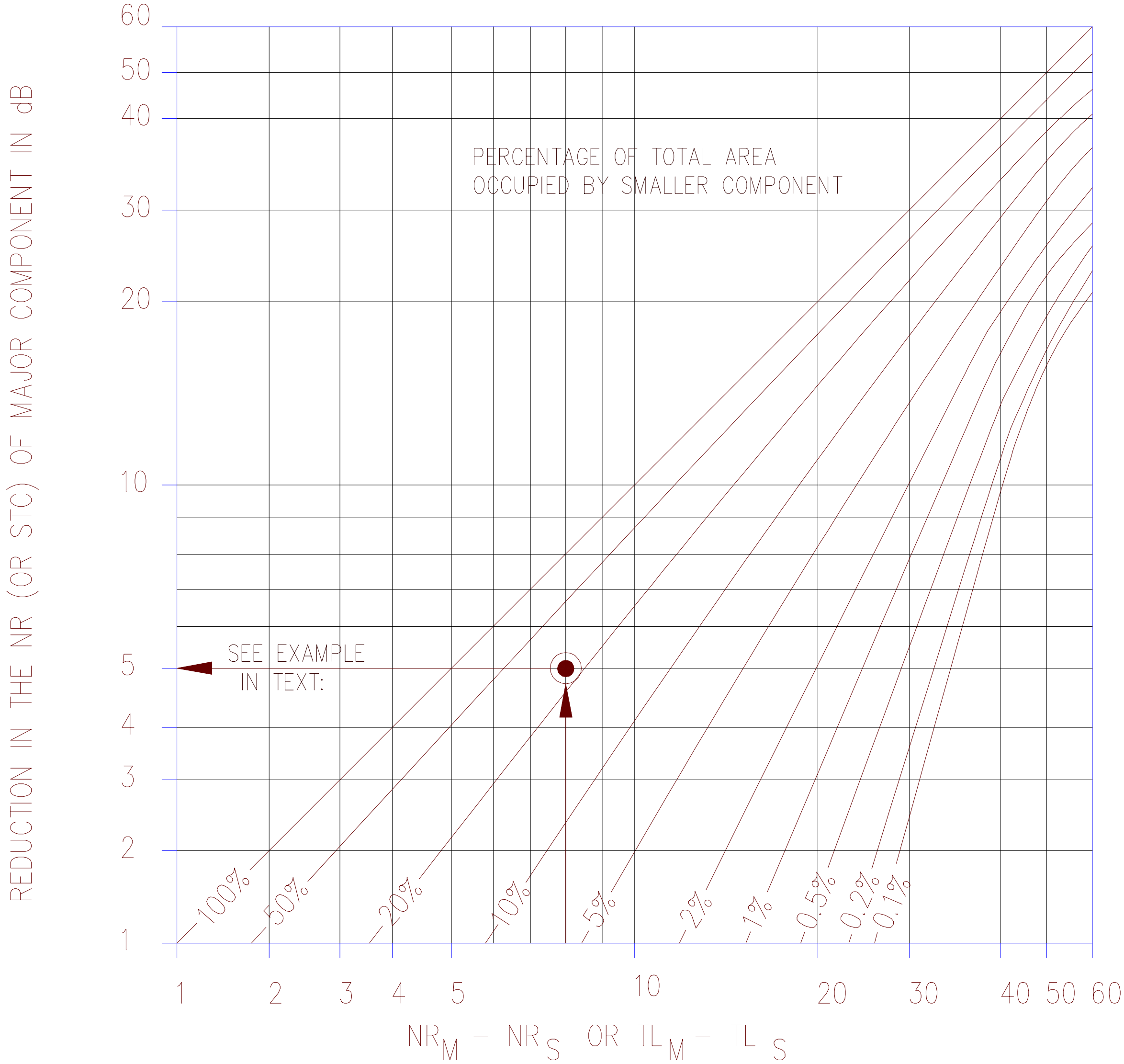
FLANKING PATHS BETWEEN EXAM ROOMS AND OFFICES

Figure 23.2



CEILING / PARTITION SOUND BARRIERS

Figure 23.3



PROCEDURE:

1. DETERMINE AREAS OF TOTAL CONSTRUCTION AND SMALLER COMPONENT AND PERCENTAGE OF TOTAL AREA OCCUPIED BY SMALLER COMPONENT.
2. SUBTRACT NR (OR STC) OF SMALLER COMPONENT FROM NR (OR STC) OF MAJOR COMPONENT [$NR_M - NR_S$ OR $STC_M - STC_S$]
3. AT INTERSECTION POINT OF THESE TWO VALUES [FROM STEPS 1 & 2] FIND REDUCTION IN THE NR (OR STC) ON LEFT MARGIN.
4. SUBTRACT THIS VALUE FROM THE NR (OR TL) OF THE MAJOR COMPONENT TO DETERMINE TOTAL NR (OR STC) OF COMPOSITE CONSTRUCTION.

NOISE REDUCTION OF COMPOSITE CONSTRUCTION TYPES
Figure 23.4

23.3 ROOM ACOUSTICS.

23.3.1 General. The character and quality of acoustics within is a space is a function of the finish materials in the room (whether they are sound absorbing or sound reflecting) and the volume and shape of the room. Adequate areas of sound absorbing materials can reduce noise within the space, make the room more comfortable because reflections are not coming from all directions, and greatly improve speech intelligibility.

23.3.3 Design Guidelines.

23.3.3.1 Ceilings. Most general purpose spaces in military health care facilities can be made comfortable for noise control and room acoustics by judicious application of suspended standard acoustic tile ceilings. In potentially loud spaces, such as a cafeteria or industrial work area, the absorbing material should be chosen to have a particularly high NRC value, perhaps .75 or greater. In spaces with high ceilings, the additional volume increases reverberation in the space, and so such rooms should have additional sound absorbing wall treatments.

23.3.3.2 Other spaces. Special environments for presentations, conferences, lectures or loud labs may require specialized room shaping analysis and special sound absorbing approaches, including additional absorbing materials on walls.

23.4 MECHANICAL AND ELECTRICAL SYSTEMS NOISE AND VIBRATION CONTROL.

23.4.1 General.

23.4.1.1 Introduction. Mechanical systems create the most pervasive noise sources in buildings. Figure 23.5 shows the range of noise levels produced by typical building equipment. The noise problem is exacerbated in modern buildings because the buildings are often lightweight structures which easily transmit sound and vibration. Care should be taken in the location, selection, and installation of mechanical equipment and in the design of the enclosing constructions. When economically practicable, major mechanical equipment such as water chillers, boilers, pumps and compressors should be located in central plants totally separated from the health facility building. Mechanical equipment that remains within the building, such as air handling units, should be located in spaces that are segregated from acoustically sensitive areas, both vertically and horizontally, by the layout of non-critical buffer spaces (such as corridors) to avoid the need for special sound isolating constructions between equipment rooms and acoustically sensitive spaces.

23.4.1.2 Mechanical Systems Design. Careful consideration must be made to the selection, location, and installation of mechanical system components to insure compatibility with the building occupants and functional requirements. The misapplication of mechanical system components and their relationship to adjacent spaces can result in unwanted noise which is often annoying and could impede the facility function. The sections that follow address specific parts of the design approach for mechanical system noise and vibration control. These parts are: duct-borne fan noise; air-generated noise; cross-talk between spaces; noise control within mechanical equipment rooms; vibration isolation; and plumbing noise. These sections present general guidelines, and do not replace detailed engineering analysis. Refer to additional requirements for mechanical system noise control in Section 8 of this document.

23.4.2 Duct-borne Fan Noise.

23.4.2.1 Introduction. All rotating equipment, and most predominantly fans in air distribution systems, generate noise because of their energy consumption and inherent design. This noise is transmitted to occupied spaces through the air distribution system, both supply and return. The selection of quieter, initially more expensive equipment is generally more economical in the long run than the selection of a less expensive type of fan that requires considerably more noise and vibration control, detailing, materials, isolators, and constructions for sound separation. When practicable, equipment should be specified and selected on the basis of low noise level output; designers should schedule the maximum sound power output, per each octave band, for air handling unit fans.

23.4.3 Air-Generated Noise.

23.4.3.1 Introduction. The movement of air for heating and ventilating systems generates noise related to turbulent airflow. Turbulent airflow is created by uneven flow distribution, higher air velocities, obstruction in the air flow, and the like. Acoustically, low or medium air velocity systems are most appropriate for use in medical facilities because low velocity distribution generally requires less energy to move the air and also because low velocity air movement greatly reduces the generation and regeneration of noise produced by high velocities.

23.4.3.2 Airflow velocities. Listed below are the approximate ranges of airflow velocities at the face of the terminal devices (diffusers and grilles) and in the last 1 to 2 meters (3 to 6 feet) of duct serving a space, required to achieve specific ambient noise levels. These noise levels are represented by NC (Noise Criteria) curves (ref. Figures 23.6) and assume no additional noise contribution due to duct-borne fan noise or air turbulence.

Noise Criterion (NC) Range	Terminal Airflow Velocity	
	meters per second	(feet per minute)
NC-25 to NC-30	1.8 to 2.2	(350 to 425)
NC-30 to NC-35	2.2 to 2.5	(425 to 500)
NC-35 to NC-40	2.5 to 3.0	(500 to 600)

23.4.4 Cross-Talk Between Spaces.

23.4.4.1 Introduction. Cross-talk is the transfer of sound, such as intelligible speech, from one room to its neighbor by way of a common unlined supply duct or by way of a common return air path (either a duct or plenum return). These air paths are efficient paths for the transmission of sound, and can negate the privacy provided by the intervening construction elements. Examination rooms and patient bedrooms will require special consideration to prevent such cross-talk.

23.4.4.2 Duct layout. Locate the outlets of connected ducts as far apart as possible. Use diametrically opposing duct elbows to reduce cross-talk. Internal acoustic lining should *be avoided (is prohibited in inpatient areas), in favor of utilizing the natural attenuating effect of longer separating duct runs, elbows, and other duct fittings.* To minimize cross-talk transmission in *supply and return* ductwork, individual room runouts should be configured as shown in Figure 23.7, where the outlets are spaced as far apart as possible. *When room return air is not ducted (plenum return), designers must consider and provide construction details for an appropriate duct/fitting attachment to achieve required attenuation*.

23.4.5 Noise Control Within Mechanical Equipment Rooms.

23.4.5.1 Introduction. Mechanical equipment rooms are noisy environments. In conditions where exposure duration in excess of 85 dBA occurs for more than 8 hours (or higher noise levels are exceed for shorter periods of time), noise mitigation procedures may be required to meet federal noise exposure guidelines (e.g., OSHA regulations) and to reduce the possibility of hearing damage; permissible exposure limitations for lower noise levels are indicated below. When designing equipment rooms which will be regularly occupied by maintenance personnel (as opposed to rooms requiring only periodic maintenance visits), designers shall consider attenuation features necessary to control noise level.

Exposure Duration per day, day in hours	sound level in dBA
8	85
6	87
4	90
3	92
2	95
1½	97
1	100
½	105
¼ and less	100 (max)

23.4.6 Vibration Isolation.

23.4.6.1 Introduction. Structure-borne sound is produced by a noise source, such as vibrating or rotating machinery, which transmits energy directly into to and through the structure. This noise is often transmitted to far-removed locations in a building and is re-radiated by wall and floor construction as airborne noise. All vibrating equipment in a medical facility should be resiliently isolated on vibration isolation systems to reduce the transmission of structure-borne noise, according to manufacturers' recommendations and guide specifications.

23.4.6.2 Equipment location. The effectiveness of vibration isolators depends upon the degree of flexibility of the supporting structural system, and it always preferable to provide resilient support from a stiff and rigid base. Because of its high degree of stiffness, the grade slab of any building is the preferred location for major generating and prime moving equipment. All mechanical equipment installed above grade should be located as close as possible over a column, load-bearing wall, or other stiff structural member.

23.4.6.3 Static deflection. The effectiveness of any vibration isolation system is determined by its static deflection (that is, deflection under load). The design of the proper static deflection is determined by the speed and horsepower of the equipment being isolated, as well as by the location of the equipment within the building and the stiffness of the supporting structure. The determination of the static deflections for specific pieces of mechanical equipment will be made using the tables in section V of TM 5-0805-4, or as recommended by the equipment manufacturer to meet specified vibration transmission limitations.

23.4.6.4 Flanking transmission. Flanking transmission of vibration energy from mechanical equipment should be minimized. All connections to vibrating equipment should be through flexible connectors, conduits, piping, or hose. All piping in mechanical equipment spaces connected to vibrating equipment should be supported by resilient ceiling hangers or floor-mounted resilient supports. Penetrations through equipment room walls and ceilings should be oversized, packed with a resilient material such as glass fiber or mineral fiber, caulked airtight, and covered with escutcheon plates where required for fire ratings. Piping should be supported on both sides of the penetrations and should not rest on the structure.

23.4.7 Plumbing Noise.

23.4.7.1 Introduction. One of the most common acoustical problems found in buildings is the noise generated by the water piping systems. Due to its easily identifiable nature, plumbing noise is one of the most disturbing and offensive types of noises encountered in building even though the noise levels are seldom excessively high. Most of the noise from piping systems is structure-borne, being transmitted along the piping throughout the building where the noise is re-radiated as airborne noise.

23.4.7.2 Piping isolation. At wall and floor penetrations, water piping runs should be free from the structure and the opening packed with a resilient insulation material and fully caulked. Water supply pipes larger than 50mm (2 inches) in diameter should be suspended from the structure on neoprene-in-shear hangers or floor-mounted on resilient supports. Flexible pipe connectors will be used to connect the supply and drain pipes to vibrating units such as garbage disposals, pot, pan and dishwashers.

23.4.7.3 Water pressure and flow velocities. High pressure and high velocity flow plumbing systems are inherently noisy due to turbulence in the fluid flow. To prevent the generation of excessive flow noise caused by turbulent water flow in the plumbing and piping systems located adjacent to sensitive areas, water pressure should be in the range of 2.8 kg to 3.5 kg per square centimeter (40 to 50 lbs./square inches).

23.4.7.4 Water hammer. The use of short, air filled branch pipes or stubs to control water hammer is not effective and should not be used, since the entrapped air in the stubs soon leaves these chambers by dissolving into the water. The most efficient means of preventing water hammer is to install one of the mechanical devices manufactured for this purpose, which employs a gas-filled stainless steel bellows to absorb the shock of the hydraulic waves by mechanical compression of the bellows. These devices are available in a variety of sizes to accommodate most fixture sizes used in buildings.

23.4.8 Isolation of Materials Handling and Transportation Systems.

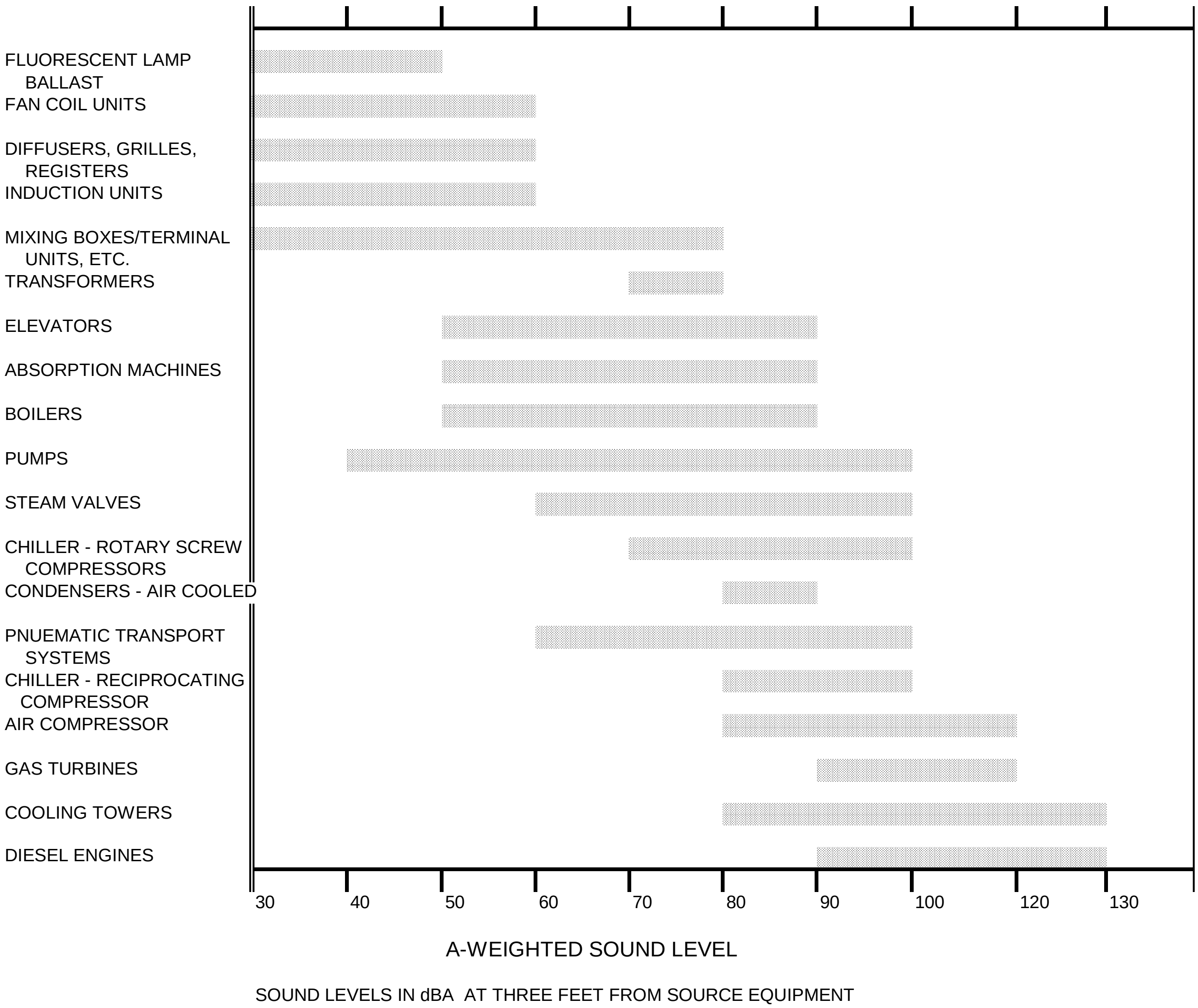
23.4.8.1 Vertical services. Chutes, pneumatic tubes, and vertical conveyors should not be located adjacent to any acoustically sensitive space, and should be resiliently isolated from the building structure at each floor penetration by means of rubber-in-shear or glass fiber isolators providing a minimum static deflection of 12.5mm (0.5 inch). The exterior of each trash chute and large pneumatic tube should be coated with a visco-elastic vibration damping compound or other damping material.

23.4.8.2 Other services. Wherever possible, other vertical and horizontal systems runs, such as pneumatic tubes, conveyors, and monorails should not be located adjacent to, over, or under any acoustically sensitive space. These systems should be isolated from the building structure by resilient hangers, isolated support traps, or resilient pads or trapeze hangers, and should have no direct physical connection with the finish ceiling system of the space below. If the horizontal runs are routed over acoustically sensitive spaces, pneumatic tubes should be coated with visco-elastic damping compound or other damping material, such as 25mm (1 inch) thick glass fiber blanket, with an impervious outer covering, such as metal foil. Alternatively, these system runs can be boxed in, encased, or wrapped with an impervious barrier material such as dense plaster, gypsum board, or a 50mm (2 inch) thick glass fiber material, 6 pounds per cubic foot density, covered with an impervious outer wrapping such as reinforced leaded vinyl or sheet lead.

23.4.8.3 Drive systems. In addition to resiliently isolating the service runs from the building structure, the drive units, transfer or diverter units, and exhauster, associated with each type of system run should also be isolated, as will the motors, pumps, compressors, gear and drive assemblies.

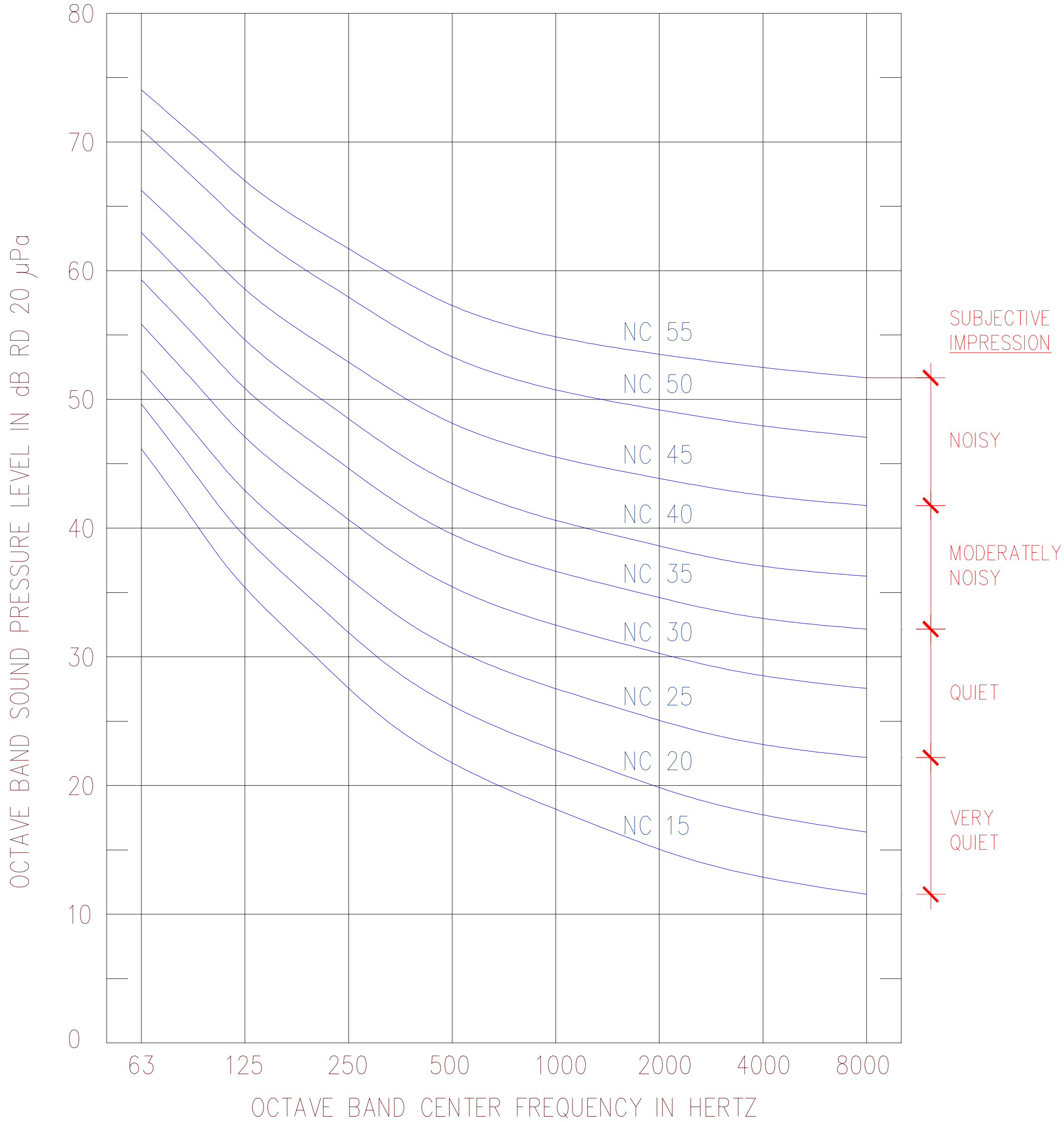
23.4.9 Emergency power systems. Emergency generators are typically located near the major power plant loads, somewhat physically isolated from acoustically sensitive areas, but such location must also be suitably close to patient care emergency loads to insure adequate service. Generator noise and vibration solutions must be considered during design. Generator exhaust location and configuration must consider visible emissions, noise levels and directionality of produced noise effects on patients, staff and neighboring facilities. Typical specifications for sound limitation should meet residential area requirements.

23.4.10 Other electrical systems. Interior dry distribution transformers and fluorescent lighting fixtures should be specified to limit intrinsic acoustic "hum" noise to non-noticeable levels in functional areas.



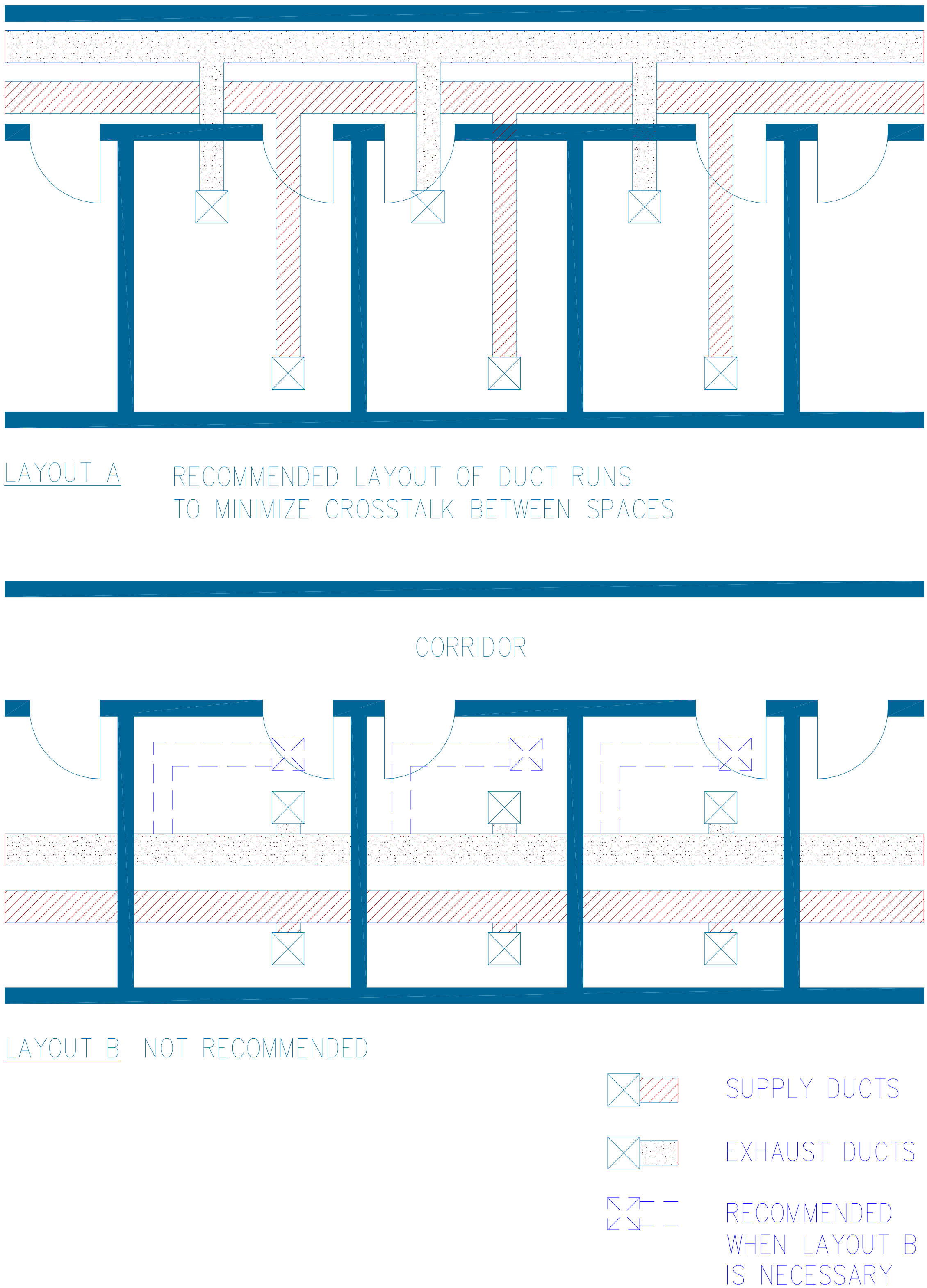
SOUND LEVELS FROM BUILDING EQUIPMENT

Figure 23.5



NOISE CRITERIA (NC) CURVES

Figure 23.6



SCHEMATIC DUCT LAYOUTS

Figure 23.7

APPENDIX E: ACOUSTICS

E.1. Introduction. This appendix covers general acoustics information, designed to help a design professional or facility program manager in understanding in more detail, individual aspects not covered in section 23 and Appendix A.

E.2 Definitions.

E.2.1. A-weighted decibels (dBA): The A-weighted scale of a sound level meter measures decibels in a manner that discriminates against lower frequencies in the same manner as does human hearing. Therefore, sound measured in dBA is a fair measure of how loud we perceive a source.

E.2.2. CAC (Ceiling Attenuation Class): CAC values measure the amount of sound that is blocked by an acoustic tile ceiling for the sound path that goes from one room, through its acoustic tile ceiling, into a standard plenum, and back through the acoustic tile ceiling into a neighboring room. The CAC value applies just to this path through the plenum, and is analogous to the STC rating for a wall. Higher values indicate a greater ability to block sound.

E.2.3 Coefficient of absorption. All materials absorb some sound, and this percentage of sound is measured (in laboratory tests) as a coefficient of absorption. Coefficients of absorption range in value from close to 0 (no absorption) to nearly 1.0 (100 % efficient); these coefficients vary as a function of frequency. Materials that are most efficient at absorbing sound include soft porous “fuzzy” materials such as glass fiber, mineral wool, carpet, curtains, acoustic tile, and other specialty materials. Materials that depend on their porosity to absorb sound should not be painted in a way which will clog their pores, and thus degrade their acoustical performance.

E.2.4. Decibels (dB). Sound energy is measured in decibels (dB), which corresponds to loudness. The decibel scale ranges from 0 dB (threshold of hearing) to over 100 dB (painful and injurious to one’s health). Decibels are a logarithmic scale, which means that you can not add decibels directly (50 dB + 50 dB equals 53 dB, and does not equal 100 dB). Discussions that follow will avoid detailed calculations or technical analysis.

E.2.5. Frequency (Hz). The frequency of vibrations for a sound source is measured in cycles per second, or Hertz (Hz), which corresponds to pitch. Human hearing responds to sound from 20 Hz (very low tones) to 20,000 Hz (very high tones). Frequencies of sound relate to types of noise sources (e.g., diesel engines produce low frequency sound, human speech carries intelligibility at higher frequencies), sound paths (some materials and constructions are better at blocking or absorbing sound at certain frequencies than at other frequencies), and the receivers (humans are most sensitive to sounds at mid- to high-frequencies of 500 Hz and above).

E.2.6. IIC (Impact Isolation Class): IIC is a single number rating system for the ability of a floor/ceiling construction system to reduce the noise of impact or structure-borne energy. Higher values indicate a greater ability to reduce impact noise.

E.2.7. NC (Noise Criteria level): NC is a single number rating system for level and spectrum of steady-state background noise levels in buildings, as determined by the noise of mechanical systems. Minimum and maximum ratings per room are listed in Appendix “A”.

E.2.8. NIC (Noise Isolation Class): NIC is the single number rating based on field tests of how well all inter-connected constructions around a room block sound. NIC will often be less than the STC rating for the same construction by about 4 to 8 decibels. The NIC ratings include the contribution of all sound paths between adjacent spaces (including doors, ceilings, windows, etc.). Higher values indicate a greater ability to block sound.

E.2.9. NR (Noise Reduction): NR is another measure of all the sound transfer between two spaces, by way of multiple paths (such as walls, floors, doors, ceilings, windows, etc.) The NR is the difference in A-weighted sound levels (dBA) from source to receiver. Higher values indicate a greater ability to block sound.

E.2.10. NRC (Noise Reduction Coefficient): NRC is a measure of the sound absorption of a material within a space. It is the average of absorption coefficients of the mid-frequencies that are most typical of general office and speech use. NRC values range from 0 to 1, with the value being rounded to the nearest .05 value. Higher values indicate a greater ability to absorb sound.

E.2.11. Source/Path/Receiver. Every acoustics problem and issue can be analyzed by looking at the separate elements that comprise the source/path/receiver outline. The source may be a neighbor talking, mechanical equipment, a vibrating pump, music from a stereo, or outside traffic. The path may be the building envelope, the intervening construction between two spaces and the multiple paths by which sound may travel, the air in a room, the building structure (in the case of structure-borne transmission), or several of these elements together. The receiver is the human occupant (patient, office worker, neighbor) whose health and welfare are the goal of the acoustical design.

E.2.12. STC (Sound Transmission Class): STC is the single number rating based on laboratory tests of how well a particular construction type blocks sound. STC values are determined from TL data (see below). Higher values indicate a greater ability to block sound.

E.2.13. TL (Transmission Loss): The ability of materials to block sound is measured in a laboratory as the Transmission Loss, TL. TL covers a wide range of discrete octave band or one-third octave band frequencies. A higher TL means that less sound is transmitted through the construction, and hence provides better sound isolation. TL is mainly useful in order to derive the single number STC value for a material (see above).